there is a regular pulsating movement in the dorsal vessel, and in the small four-chambered bodies in the 9th segment [ovaries]. The entrance of air into the posterior pair of spiracles seems to give the initial impulse which travels so rapidly along the series and its ramifications that almost immediately the head of the insect begins to move from side to side as if affected by the same influences which affected the other parts. This occurs when the leafy covering of the larva is cut open and light and air admitted.

The first conscious effort of the larva when its sheath [nest] is opened is directed toward the elaboration of silk fluid with which to enclose itself once more within its case. With this purpose it eats rapidly and the silk fluid is seen at the same time accumulating in and near the thoracic segments. The larva uses its short, black, front pair of feet to unite the threads which it spins back and forth, forming a cord of 50 to 75 threads, as may suit its purposes.

The pupa exhibits no specially interesting features. It is pale green, with faint traces of the outer set of tracheae still visible: broad at anterior end, with a sharp black spine from its extremity, by which it is attached to a mass of fine white silk. Body cylindrical, tapering at anal end. A loose girdle of silk passes around its body, and its entire length rests against a delicate layer of white silk. If disturbed it moves with great rapidity. It transforms in ten days. The motions of the imago of this hesperian are very rapid.

I have not sufficient data to make this an exhaustive monograph, but other students may have added what I have omitted. If not, we may leave to time and diligence the further discovery of such facts as are yet unknown.

CIRCULATION OF BLOOD IN THE LARVA OF *HYDROPHILUS*.

BY GEORGE DIMMOCK, CAMBRIDGE, MASS.

Examination of living larvae of *Hydrophilus* under the microscope, the past summer, revealed the circulation of blood in their antennae and trophi, which is so distinctly visible and so curious in its directions as to be worthy of notice.

The blood of the larva of *Hydrophilus*, after leaving the anterior extremity of the dorsal vessel or heart and entering the head, divides itself into two lateral branches, one of which descends on each side of the oesophagus, the two branches reuniting beneath the oesophagus, a little anterior to their division on its upper side, to form a median stream. Between the point where the streams separate and reunite, each stream gives off three branches, all of which flow in the same direction as the middle stream formed by the reunion of the two lateral streams, that is, toward the anterior part of the head. The median stream formed by the reunion of the two lateral streams, which is, of course, more ventral in position than the six other streams, enters the middle of the labium, and passes along the dorsal half of that organ until it nearly reaches the bases of the labial palpi. Here the stream turns back laterally and ventrally,

so that the returning stream is along the ventral half and in both lateral portions of the labium. Each of the two streams of blood next toward the dorsum, from the one which supplies the labium enters the outer side of a maxilla, flows along the outer side nearly to the distal end of the basal joint of the maxilla, and returns along the inner side of the joint to the head. The two streams next in order, as the dorsal side of the head is approached, are those that supply blood to the mandibles. Each of these streams enters the mandible on its inner side, flows nearly to its tip, and returns on its outer side. Dorsally from the streams supplying the mandibles are the streams that flow into the antennae, which, in the larvae of *Hydrophilus* are used as trophi. Each stream enters its antenna on the inner side, flows to the distal end of the basal joint, and returns on the outer side of that joint to the head. After their return to the head, the currents of blood from the antennae and trophi are lost among the muscles of the head.

I have attempted, in fig. 5, by arrows, to give a more readily comprehensible idea of the direction and extent of the above-mentioned streams of blood, than can be given by mere description. To complete the figure one should imagine a stream of blood toward the head, beneath the arrow in the middle of the labium; that is, with the head in the position indicated in the figure, the microscope can be focused first on a stream flowing outward in the labium, and then, with the fine adjustment, the tube of the microscope can be lowered until a return stream toward the head is brought into focus. I have not attempted to indicate, on the sketch, the currents of blood in the head, as they would too greatly complicate the figure.

FIG. 5.

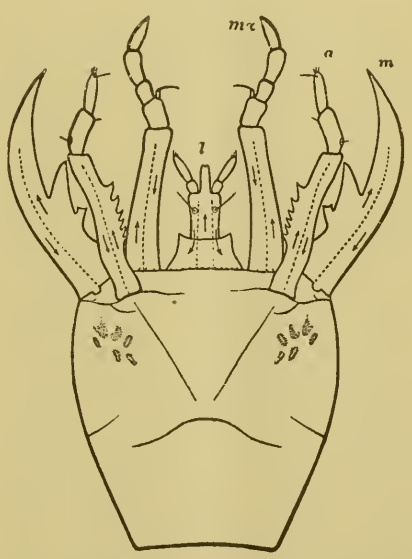

FIG. 5.—Dorsal view of head of young larva of *Hydrophilus ?piceus*. Direction of blood-currents in the appendages indicated by arrows. Dotted lines indicate partitions between blood-currents. *a*, antenna; *m*, mandible; *mx*, maxilla; *l*, labium. Magnified 20 diameters.

The currents of blood are not, of course, confined in cylindrical arteries and veins, as they are in the vertebrates, and, consequently, I have used the terms streams and currents of blood. These streams of blood occupy nearly the whole interior cavity of the appendages in the larvae of *Hydrophilus*, the outward and return currents being separated by partitions, of apparently a porous nature, which are represented in the figure by dotted lines. These partitions, like those described by C. G. Carus[1] in the abdominal appendages of the larvae of

1 Carus, C. G. Entdeckung eines einfachen vom Herzen aus beschleunigten Blutkreislaufes in den Larven netzflüglicher Insecten. Leipzig, 1827.

Agrion puella, are very delicate, and extend, in the antennae, mandibles and maxillae, from the upper to the lower chitinous walls. In no case have I observed corpuscles of blood pass through these porous partitions, but they may not be impervious to the fluid portion of the blood. They serve to guide the currents of blood and to cause it to circulate in the appendages. It is not necessary for these porous partitions to extend into the apical joints of each appendage, the blood which fills these joints not needing rapid changing. Carus notes that, in the larva of *Ephemera vulgaris*, the blood has a distinct outward and return current in the basal joint of each antenna. This is the case, as will be seen by the figure, in the antennae of the larva of *Hydrophilus*, where the partition between the two streams ends just posterior to the distal end of the basal joint of each antenna.

Verloren[2] notes that, in the antennae of the larvae of *Ephemera diptera* he had never been able to observe the circulation of the nutrient fluid, except in the first joint, where the current enters on the inner side and returns on the outer side. The direction and extent of the currents of blood in the antennae are the same in the larva of *Ephemera diptera* as in that of *Hydrophilus*, but, as the literature at my command fails to give the necessary data in regard to the currents of blood in the antennae of other insects, and I have not been able to obtain specimens suitable for further observation, it is unsafe to predict that the currents of blood in the antennae of insects generally follow a similar course.

It will be seen, at first glance, on the figure, that, with one exception, all the streams of blood have their outward course on the inner side of each appendage; the exception is in the maxillae, where the outward course of the blood is on the outer side. It would be interesting to know if, in other insect larvae, the streams of blood entered the maxillae on the outer and returned on the inner side.

As the circulation in the appendages of the head of the larvae of *Hydrophilus* has no capillaries, the progress of the blood is so little checked that one can count the pulsations of the heart as well in the returning currents as in the outgoing ones.

For the purpose of detailed study of the circulation of the blood, not only in the antennae and trophi but in all parts of the body, the young larvae of *Hydrophilus* offer special advantages, on account of their transparency, which is so great that their blood-corpuscles can be readily seen, under the microscope, without using extremely high powers. The egg-cases of *Hydrophilus* can be collected in summer,[3] and the larvae easily reared in a small aquarium. If a suitable aquarium be chosen, and placed beneath any kind of a fly-trap, in such a way that the flies captured will fall, living, into the water, a healthy brood of larvae of *Hydrophilus* can be fed with a minimum of attention.

2 Verloren, M. C. Mémoire en résponse à la question suivante: Éclaircir par des observations nouvelles le phénomène de la circulation dans les insectes . . . 1844.

3 See paper by W. H. Garman, entitled, "The egg-case and larva of *Hydrophilus triangularis* Say." (Amer. naturalist, Aug. 1881, v. 15, p. 660-663, fig. 1-3.)

Paris, France, 16 Dec. 1881.